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Is There a Biomedical Explanation for Socioeconomic Differences in Incident Mobility Limitation?

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Background. The association between low socioeconomic status and poor physical functioning has been well described; biomedical factors may play an important role in explaining these differences. This study examines the association between socioeconomic status and incident mobility limitation in well-functioning older adults, and seeks to determine whether this link could be explained by biomedical factors.

Methods. Data were obtained from 3066 men and women, aged 70–79 years from Pittsburgh, Pennsylvania and Memphis, Tennessee participating in the Health, Aging and Body Composition (Health ABC) study. Three indicators of socioeconomic status were used: education, income, and ownership of financial assets. Mobility limitation was defined as reporting difficulty walking 1/4 mile or climbing 10 steps during two consecutive semiannual assessments over 4.5 years. Biomedical factors included a wide range of diseases (e.g., heart and cerebrovascular disease) and biological risk factors (e.g. hypertension, poor pulmonary function, and high serum levels of inflammatory markers).

Results. Adjusted hazard ratios of incident mobility limitation were significantly higher in those persons with low education, low income, and few assets. Hazard ratios ranged from 1.66 to 2.80 in the lowest socioeconomic groups. Additional adjustment for biomedical factors reduced the hazard ratios by an average of 41% for education, 17% for income, and 29% for assets.

Conclusion. Biomedical factors can account for some of the association between socioeconomic status and incident mobility limitation. However, to reduce physical disabilities and, in particular, the socioeconomic differences therein, it may not be sufficient to solely intervene upon biological risk factors and risks of diseases.

THE association between low socioeconomic status (SES) and poor physical functioning has been well described (1–4), and several authors hypothesize that biomedical factors such as diseases and biological risk factors play an important role in explaining these differences (5–7). Low SES is a risk factor for cardiovascular disease and stroke, as well as a variety of other diseases (8–10). Obesity, high blood pressure, glucose intolerance, and reduced lung function are also more prevalent among low SES groups in comparison with high SES groups (11–14). Several of these biomedical factors have been directly related to adverse functional outcomes (4,15,16). As important as disease and established disease risk factors may be in predicting function, data are emerging to suggest that certain inflammatory markers also play an important role, independent of prevalent clinical disease (17–20). Two recent studies (21,22) also show that persons with low SES have higher serum levels of inflammatory markers than do persons with high SES.

Despite the knowledge that low SES is related to both poorer function and increased prevalence of many diseases and their risk factors, the extent to which biomedical factors can explain the relationship between low SES and functional decline has not been studied extensively. Knowledge of possible biological pathways underlying the association between SES and poor functional outcomes may give insight into potential ways of reducing SES differentials in physical functioning.

In the present study, we examine the association between SES and incident persistent mobility limitation in a large community-based cohort of well-functioning older adults, and seek to determine whether this link can be explained by biomedical factors.

Methods

Study Population

The Health, Aging and Body Composition (Health ABC) study is a longitudinal cohort study consisting of 3075 well-functioning, 70- to 79-year-old, black and white men and women. Participants were identified from a random sample of white Medicare beneficiaries and all age-eligible community-dwelling black residents in designated ZIP code areas surrounding Memphis, Tennessee, and Pittsburgh, Pennsylvania. Participants were eligible if they reported themselves to be well-functioning and free of difficulty with

any activity of daily living. 'Well-functioning' was defined as having no difficulty in either walking 1/4 mile or going up 10 steps without resting. Participants were excluded if they reported a history of active treatment for cancer in the prior 3 years, planned to move out of the study area within the next 3 years, or were currently participating in a randomized trial of a life-style intervention. Baseline data, collected between April 1997 and June 1998, included an in-person interview and a clinic-based examination, with evaluation of body composition, clinical and subclinical diseases, and physical functioning. Four and a half years of follow-up were used in this study. For nine participants, outcome data or SES data were missing, leaving 3066 participants for the present analyses. All participants signed informed written consent approved by the institutional review boards of the clinical sites.

Measures

SES.—Three indicators of SES were used: education, family income, and ownership of financial assets. Categories for education were: less than 12 years, 12 years, and more than 12 years. Family income was measured by adding all reported income components of all household members. Income was defined as any source of income including: wages, salaries, social security or retirement benefits, help from relatives, and rent from property. Four categories of family income were distinguished: less than $10,000, between $10,000 and less than $25,000, between $25,000 and less than $50,000, and greater than or equal to $50,000. Because of the large number of participants with missing income data, a fifth category was created for this group. Financial assets included: money market account, saving bonds or treasury bills, home ownership or investment property or housing, a business or farm, stock or stock mutual funds, an individual retirement account (IRA) or KEOGH account, and other investments. Three categories were created: none, one or two, and three to seven (23). Rather than use a dichotomous variable of any versus no assets, categories were used because the literature has shown that various SES gradients have significant effect on health outcomes (24).

Incident persistent mobility limitation.—The occurrence of mobility limitation over 4½ years of follow-up was determined every 6 months, at study assessment visits (12, 24, 36, and 48 months after baseline), or during telephone follow-up assessments (6, 18, 30, 42, and 54 months after baseline). Incident persistent mobility limitation was considered to be present when a person reported any difficulty walking one quarter mile or climbing 10 steps at two semiannual follow-up assessments. The requirement that mobility limitation needed to be present at two consecutive assessments selected participants with more chronic and severe functional limitation; therefore, this outcome was thought to be a more reliable indicator of a clinically relevant change in functional status. The incidence of mobility limitation was adjudicated by a special Health ABC study committee that considered additionally available information such as reason for missing study contact (in nursing home, severe illness) and proxy information for those participants who died.

Biomedical factors.—Possible biomedical explanatory variables cover a wide range of clinical and subclinical diseases. Baseline presence of diseases was determined using standardized algorithms considering self-report, use of specific medications, and some clinical assessments. Baseline prevalent cancer was based on self-reports of cancer or malignancy and/or use of anticancer medication. The presence of heart disease was defined as having coronary heart disease and/or congestive heart failure. Cerebrovascular disease was defined as a history of stroke or transient ischemic attack. Peripheral arterial disease was based on self-reports of intermittent claudication or a history of lower extremity bypass or angioplasty. Three categories, using American Diabetes Association criteria, were distinguished for glucose intolerance: not impaired (fasting glucose level $<$100 mg/dl), impaired fasting glucose (fasting glucose level between 100 mg/dl and 126 mg/dl), and diabetes mellitus (fasting glucose level $>$126 mg/dl). Hypercholesterolemic persons had high total cholesterol levels ($\geq$240 mg/dl) and/or high low-density lipoprotein cholesterol levels ($\geq$130 mg/dl) or were being treated with lipid-lowering drugs (25). Triglyceride levels were considered high if $>$150 mg/dl, and high-density lipoprotein cholesterol levels were considered low if $<$40 mg/dl in men and $<$50 mg/dl in women (26). For hypertension, four categories were created: normotensive (systolic pressure $<$140 mmHg and diastolic pressure $<$90 mmHg); normotensive and treated with blood pressure-lowering drugs; hypertension stage 1 (systolic pressure $\geq$140 mmHg or diastolic pressure $\geq$90 mmHg); and hypertension stage 2 (systolic pressure $\geq$160 mmHg or diastolic pressure $\geq$100 mmHg) (27). Two variables for pulmonary function were used: a poor forced expiratory volume in 1 second/forced vital capacity ratio (FEV_1/FVC) of 70% or lower, and percentage predicted FEV_1 of 80% or lower (28,29). Body mass index (BMI) was categorized as lower than 25 kg/m^2, between 25 and 30 kg/m^2, and higher than 30 kg/m^2. Knee pain was considered if reported to be present at least 1 month of the past year. Ankle arm blood pressure index was considered indicative of peripheral arterial disease if lower than 0.9 (30). Finally, serum level of three inflammatory markers were assessed: interleukin-6 (IL-6), C-reactive protein (CRP), and tumor necrosis factor-α (TNF-α) (20). Each biomarker variable was dichotomized, where inflammation was defined as being in the highest tertile of IL-6 ($\geq$2.40 pg/ml), CRP ($\geq$2.55 mg/L), and TNF-α ($\geq$3.72 pg/ml). In addition, an inflammation index was calculated as the number of inflammatory markers in the highest tertile, which has been shown to be an important predictor of incident mobility limitation (20).

Sociodemographics.—Sociodemographics included age, sex, race (black, white), study site (Memphis, Pittsburgh), and marital status (never married, previously married, married). For the analyses with family income we also controlled for whether (yes/no) people had household members other than their spouse.

Statistical Analyses

Analyses were performed using SPSS (version 11.5; SPSS Inc., Chicago, IL). To determine if there were differences in the incidence of mobility limitation between SES groups, unadjusted Cox proportional hazard regression models were fitted. To determine if there were differences in

prevalences of the biomedical variables between SES groups, the chi-square test was used. To evaluate the association of biomedical factors with time to incident persistent mobility limitation, Cox proportional hazard regression models were fitted, adjusting for sociodemographics. Cox proportional hazard regression models were also fitted to study the association of SES on time to incident mobility limitation. Persons surviving with no evidence of incident limitation were censored at the last study visit, those dying with no evidence of incident limitation were censored at time of death, and those lost to follow-up were censored at their last interview. Two models were fitted; the first model was adjusted for sociodemographics. The second model contained all variables of the first model as well as the biomedical variables. To determine the role of biomedical factors, a percentage reduction in hazard ratio (HR) from model 1 was computed: $(HR_{model\ 1} - HR_{model\ 2})/(HR_{model\ 1} - 1)$.

Results

Figure 1 shows the incidence rate per 1000 person-years of incident mobility limitation according to SES. A p value for trend was statistically significant ($p < .001$) for all three SES indicators. More people with low SES had incident mobility limitation than did those with high SES. Results are shown for black and white persons together because interaction terms between any of the SES indicators and race were not statistically significant (all $p > .10$).

In further analyses we used only those biomedical variables that were statistically significant predictors of incident persistent mobility limitation; because of their nonsignificance; baseline presence of cancer and hypercholesterolemia were not further considered. All other biomedical factors were significant predictors of incident mobility limitation, adjusted for sociodemographics (not tabulated). Especially strong predictors were having three inflammatory markers in the highest tertile (HR: 3.21, 95% confidence interval [CI]: 2.65, 3.89), peripheral arterial disease (HR: 2.42, 95% CI: 1.97, 2.96), and knee pain (HR: 2.20, 95% CI: 1.93, 2.50).

Generally, the prevalence of disease and biological risk factors was higher in low SES groups except for high triglyceride levels and low high-density lipoprotein cholesterol levels, for which the prevalence was higher in high SES groups. Glucose intolerance, hypertension, low predicted FEV_1, high BMI, low ankle arm blood pressure index, high serum levels of IL-6 and CRP, and having three inflammatory markers in the highest tertile were statistically significantly associated with low education, low income, and few assets (Table 1).

HRs of incident mobility limitation, adjusted for sociodemographics, were significantly higher in low SES groups compared to the highest SES group (Table 2, model 1). Low income showed a particularly increased risk: HRs were 2.80 (95% CI: 2.06, 3.81) in the income group less than $10,000, and 1.82 (95% CI: 1.40, 2.36) in the income group $10,000 to less than $25,000 compared to that of those participants with an income greater than or equal to $50,000. Strong associations were found between SES and incident mobility limitation for all three SES indicators. When all SES indicators were included in one analytic model, all three indicators remained significant predictors of incident mobility limitation. Therefore education, income, and number of assets all had an independent effect on incident mobility limitation.

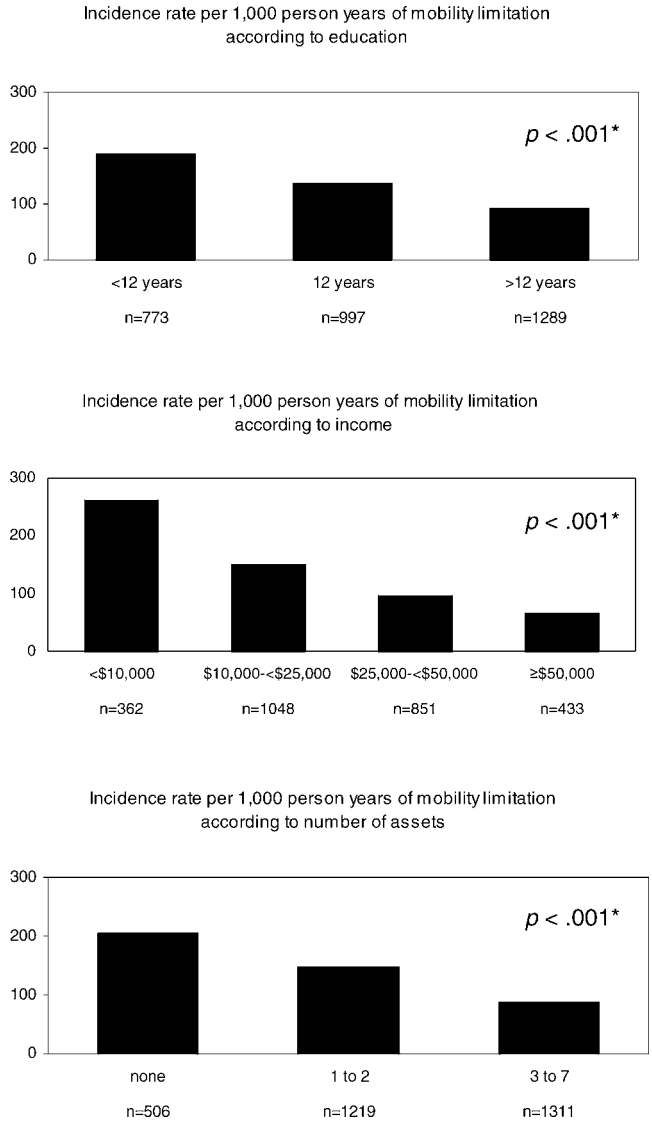

Figure 1. Incidence rate per 1000 person-years of mobility limitation according to socioeconomic status. *p value based on unadjusted survival analyses.

Biomedical factors (model 2) could explain a substantial part of the SES gradient in incident mobility limitation. The largest reduction in HRs was found for education; 48% for the group with 12 years of education and 33% for the group with less than 12 years of education (41% on average). Biomedical factors decreased the HRs by an average of 17% for income and 29% for the number of assets. Figure 2 shows the biomedical factors that reduced the HRs for the lowest SES group versus the highest SES group by more than 5%, adjusted for sociodemographics. High serum levels of inflammatory markers and high BMI decreased the HRs by more than 5% for all three SES indicators.

Table 1. Distribution (%) of Biomedical Factors by Education, Income, and Number of Assets

	Education				Income					No. of Assets			
Biomedical Factors (%)	<12 y	12 y	>12 y	*p* Value	<$10,000	$10,000–<$25,000	$25,000–<$50,000	≥$50,000	*p* Value	None	1–2	3–7	*p* Value
Heart disease	18.3	17.0	17.2	.75	16.6	17.8	17.5	18.5	.92	18.0	17.0	17.2	.87
Cerebrovascular disease	7.7	6.7	7.6	.63	8.7	8.7	6.6	5.6	.11	9.0	7.4	6.7	.24
Glucose intolerance													
Not impaired	59.9	65.0	67.4	<.001	59.0	63.0	65.1	68.8	.02	62.1	62.6	67.6	<.001
Impaired fasting glucose	22.4	21.6	21.0		21.6	23.1	21.9	19.3		18.6	21.9	22.4	
Diabetic	17.8	13.4	11.5		19.4	13.9	13.0	11.9		19.4	15.6	10.0	
Triglycerides >150 mg/dl	23.9	34.3	31.6	<.001	24.8	30.4	33.8	32.8	.01	25.2	28.0	35.0	<.001
HDL cholesterol <40 mg/dl in men, <50 mg/dl in women	26.7	31.0	29.7	.13	24.9	28.9	32.7	27.7	.07	28.7	27.4	31.6	.06
Hypertension													
Normotensive	28.1	28.0	34.9	.001	24.2	26.4	34.4	39.0	<.001	25.6	28.3	35.4	<.001
Normotensive with medications	29.2	31.7	29.8		32.2	32.0	28.7	29.3		33.5	29.9	29.5	
Stage 1	27.9	26.6	24.5		26.4	27.8	24.7	23.1		26.0	28.5	23.8	
Stage 2	14.8	13.7	10.8		17.1	13.8	12.3	8.5		15.0	13.2	11.3	
FEV_1/FVC <70%	24.0	21.2	20.4	.18	24.3	22.7	21.5	18.3	.19	20.1	23.4	20.3	.14
Predicted FEV_1 <80%	28.7	22.3	22.7	.004	28.6	24.5	24.6	19.5	.04	23.8	26.8	21.6	.01
Body mass index													
<25 kg/m^2	28.0	29.6	36.9	<.001	29.8	30.1	34.5	35.8	<.001	27.0	31.1	35.3	<.001
25–30 kg/m^2	40.0	42.6	43.5		35.3	41.2	44.9	46.4		36.0	41.2	45.8	
>30 kg/m^2	32.0	27.8	19.6		35.0	28.7	20.6	17.8		37.0	27.7	19.0	
Peripheral arterial disease	6.4	4.7	5.1	.30	6.1	5.4	5.2	4.0	.60	6.6	5.5	4.7	.25
Ankle arm blood pressure index <0.9	19.4	16.4	10.9	<.001	20.7	16.2	11.9	7.5	<.001	20.6	17.5	9.0	<.001
Knee pain	18.7	17.5	14.2	.01	20.4	17.9	14.6	14.5	.03	16.9	17.0	15.6	.60
Highest tertile IL-6	37.5	34.5	29.5	<.001	40.5	34.7	32.0	26.5	<.001	38.7	36.4	27.9	<.001
Highest tertile CRP	38.7	34.8	28.6	<.001	43.8	36.6	27.1	28.2	<.001	39.4	36.7	27.6	<.001
Highest tertile TNF-α	33.5	35.6	31.4	.12	31.8	35.3	34.2	31.3	.42	30.8	34.5	33.2	.35
Inflammation index*													
None high	36.6	34.9	43.9	<.001	33.1	35.2	41.1	45.9	<.001	36.1	34.7	44.3	<.001
1 of 3 high	30.2	36.7	31.6		31.6	35.3	33.5	31.2		30.1	35.0	32.2	
2 of 3 high	24.1	20.3	18.7		26.3	21.2	19.4	17.2		26.3	21.8	17.2	
All 3 high	9.2	8.0	5.8		9.0	8.4	6.0	5.6		7.6	8.5	6.4	

Note: HDL = high density lipoprotein; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; IL-6 = interleukin-6; CRP = C-reactive protein; TNF-α = tumor necrosis factor-α.

*The number of inflammatory marker levels (IL-6, CRP, TNF-α) within the highest tertile.

Discussion

In a well-functioning older population, low SES predicted an increased incidence of mobility limitation during 4½ years of follow-up. Biomedical factors explained a substantial part of the SES differentials in mobility limitation incidence. On average, 41% of the educational differences in mobility limitation incidence was explained by biomedical factors; this was 17% for income and 29% for the number of assets. However, even after taking into account a wide range of diseases and biological risk factors, persons in the lowest SES group still had a significant increased risk of mobility limitation incidence. HRs still ranged from 1.47 to 2.64 in the lowest SES groups compared to the highest SES groups. HRs were more modest in the middle SES groups compared to the highest SES groups. High serum levels of inflammatory markers, high BMI, and hypertension were found to be the most important biomedical variables in reducing the HRs for SES. It is notable that these variables measured biological characteristics rather than diseases. These biological risk factors have in common that they are risk factors for a wide variety of health outcomes and may represent indicators of disease severity.

Relatively few studies in older people have investigated the relationship between SES and functional outcomes (31–33). Studies have found that the relationship between SES and health outcomes were weaker in people aged 65 or older compared to younger people. In addition, it has been argued that disparities in income diminish after retirement. In our study, the effect of SES on poor functional outcomes in elderly persons was still quite strong.

Besides biomedical factors there may also be other factors that explain the association between SES and mobility limitation. These factors may be related to behavioral or psychosocial factors. Low SES is related to many adverse behavioral factors, such as smoking status and excessive alcohol consumption that in turn are related to poor health outcomes (3,6,34). In this study, the contribution of

Table 2. Hazard Ratios (HR) and 95% Confidence Interval (CI) of Incident Mobility Limitation by Education, Income, and Number of Assets

	Model 1*		Model 2†		
Socioeconomic Status	HR	95% CI	HR	95% CI	% Red.‡
Education					
>12 y	1.00		1.00		
12 y	1.33	1.13, 1.56	1.17	1.00, 1.38	48
<12 y	1.70	1.42, 2.04	1.47	1.23, 1.77	33
Income					
≥$50,000	1.00		1.00		
$25,000–<$50,000	1.39	1.07, 1.80	1.33	1.02, 1.73	15
$10,000–<$25,000	1.82	1.40, 2.36	1.61	1.24, 2.09	26
<$10,000	2.80	2.06, 3.81	2.64	1.93, 3.61	9
Missing	1.55	1.15, 2.09	1.45	1.07, 1.96	18
No. of assets					
3–7	1.00		1.00		
1–2	1.28	1.08, 1.51	1.20	1.02, 1.42	29
None	1.66	1.35, 2.04	1.47	1.19, 1.81	29

*Model 1: adjusted for age, sex, race, study site, other household members for income, and marital status.

†Model 2: adjusted for age, sex, race, study site, other household members for income, marital status, and biomedical factors.

‡Percentage reduction in hazard ratio from model 1 computed by $(HR_{model\ 1} - HR_{model\ 2})/(HR_{model\ 1} - 1)$.

biomedical factors in explaining SES difference in incident mobility limitation is similar when we adjust for smoking status (current, former, never smoker), alcohol use during the past year (0, <1, 1–7, >7 drinks per week), and physical activity (total kilocalories per kilogram per week) in both models (data not shown). There is also evidence that psychosocial factors, such as control beliefs and stress, play an important role in functional outcomes (35), and also in the association between SES and poor functional outcomes (36).

This study has some limitations. First, information on mobility limitation was based on self-report. Second, only limited information was available on the severity of baseline diseases. It must be acknowledged that the approach followed is limited by both the comprehensiveness of the panel of biomedical factors considered and the reliability with which these factors have been assessed. We cannot exclude the possibility that, had the underlying biomedical factors been measured more exactly, the diminution in the strength of the SES effect may have been larger. Third, only baseline data on biomedical factors were analyzed, so the association between SES on the one hand and biomedical factors on the other hand might have resulted from reverse causation; therefore, biomedical factors could have partly confounded the link between SES and mobility limitation (37–39). If present, it is likely that this selection effect would have had a larger effect on income and assets than on education, as the latter indicator is less sensitive to change during adulthood. However, in this study, the same results were found across all SES indicators (including education) so reversed causation is not very likely.

Our study also has several strengths. First, the study consists of a large cohort of older black and white adults in which loss to follow-up for our outcome was very limited (<4%). Second, because of the longitudinal character of our study we establish that SES precedes the development of

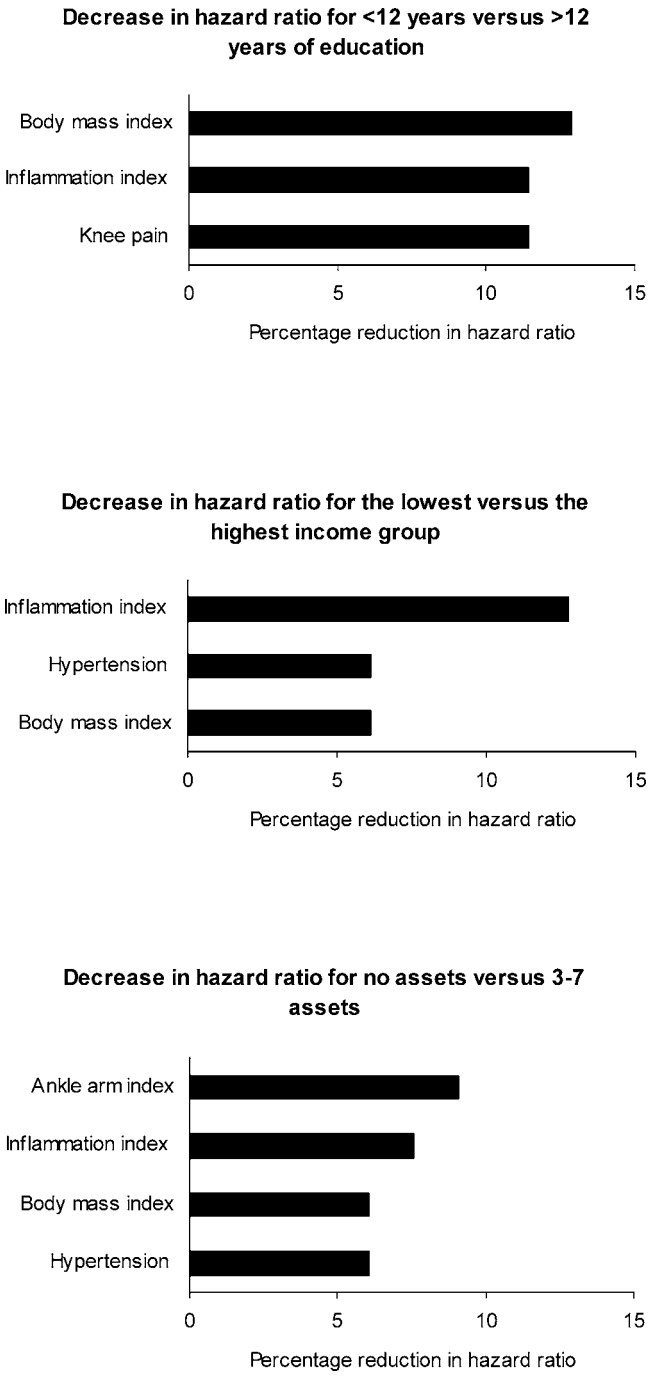

Figure 2. Biomedical factors that reduced the hazard ratio for the lowest versus the highest socioeconomic status group by more than 5%, adjusted for age, sex, race, study site, and marital status.

mobility limitation. Third, we had information on a wide variety of diseases and biological risk factors that allowed for a more comprehensive assessment than has been possible previously. Fourth, all participants were well-functioning at baseline, so the study was designed to determine incident functional limitation. Mobility limitation is the most important outcome in the Health ABC study because of the need to identify risk factors at a stage of age-related decline that would be amenable to preventive interventions.

Summary

There is a strong association between low SES and incident mobility limitation in older persons. Part of this association could be explained by biomedical factors. This study suggests that biomedical factors are important in the mechanism underlying the association between SES and poor functional outcomes. However, to reduce physical disabilities and, in particular, the SES differences therein, it may not be sufficient to solely intervene on biological risk factors and risks of diseases.

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